Enhancing Functional Efficiency and Quality of Life through Revascularization Surgery in Peripheral Arterial Disease: A Comparative Analysis of Objective and Subjective Indicators

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Background: This study aimed to compare the ankle-brachial index (ABI), maximal claudication distance (MCD), pain-free walking distance (PFWD), claudication pain, and quality of life (intermittent claudication questionnaire [ICQ]) before and 3 months after revascularization surgery in 98 patients diagnosed with peripheral arterial disease (PAD) at a single center in Poland.

Material/Methods: Ninety-eight patients were examined (77% men, 23% women, 65.65±7.27 years old), diagnosed with PAD, and qualified for revascularization. The diagnosis of PAD was made on the basis of ABI ≤0.9 and medical records. The patients underwent a noninvasive examination, including measurement of ABI (by Doppler with the EZ8 probe), assessment of the quality of life by ICQ, distance of intermittent claudication on a treadmill using the Gardner-Skinner protocol (including PFWD and MCD), and pain intensity during walking (numeric rating scale [NRS11]). The assessment was carried out twice: 1 to 5 days before surgery and 3 months after surgery.

Results: There was an increase of ABI (0.4 vs 0.62, \( P < 0.001 \)), PFWD (26.64 vs 80.21, \( P < 0.001 \)), MCD (60.08 vs 181.85, \( P < 0.001 \)), and ICQ (79.92 vs 60.23, \( P < 0.001 \)) and reduction of PFWD pain (7.26 vs 6.05, \( P < 0.001 \)) and MCD pain (9.24 vs 8.11, \( P < 0.001 \)).

Conclusions: Revascularization surgery improved the ABI and patients functional efficiency expressed in the improvement of subjective indicators PFWD, MCD, NRS11, and ICQ. Patients who had a longer duration of disease had worse outcomes after revascularization. More attention should be paid to increasing access to preventive examinations aimed at early detection of PAD and the possibility of implementing conservative treatment.

Keywords: Angioplasty • Ankle Brachial Index • Peripheral Arterial Disease • Atherosclerosis • Quality of Life

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Background

Increased attention is being given to assessing the distance of intermittent claudication and quality of life in patients with peripheral arterial disease (PAD), which is affected by the rising incidence of atherosclerosis in society [1]. PAD is increasingly recognized as an important cause of cardiovascular morbidity and mortality, which affects more than 230 million people worldwide [2]. According to the National Health and Nutrition Examination Survey, the prevalence of PAD is about 15% in individuals aged ≥70 years, but about 1% in those aged 40 to 49 years [2,3]. PAD is strongly linked with a heightened risk of death. According to statistics published in 2019, PAD was listed as the leading cause of death among 11,753 people out of a total of 58,210 recorded deaths [3]. Risk factors for atherosclerosis include hypertension, smoking, low activity level, and improper diet [4-11]. PAD is a narrowing and eventual complete occlusion of the main arteries that supply blood to the lower extremities. This causes pain and impaired gait economy, which limits the ability to move and reduces the level of physical activity of patients. Restricted blood flow to the limbs can cause pain in the thigh, buttock, or calf when walking, which is called intermittent claudication. Muscle pain, which is caused by reduced blood flow in the lower extremities, negatively affects the quality of life of patients with PAD [12]. PAD diagnostics include measurement of the ankle-brachial index (ABI), physical examination (pulse assessment, lower limb temperature), Doppler ultrasound, computed tomography and magnetic resonance angiography (MRA) [13]. The main goals of treating patients with PAD are to reduce cardiovascular risk and improve walking ability [14]. The basis of PAD treatment is lifestyle modification and eliminating risk factors, such as smoking, obesity, diabetes, hypertension, and hypercholesterolemia [15]. Treatment options for PAD depend on the stage of the disease and manifested symptoms. In the first place, treatment with exercise therapy is recommended, namely walking until moderate pain is achieved, with breaks for rest. It is recommended to train 3 to 4 times a week for 30 to 45 min [16]. In the treatment of PAD, pharmacotherapy is also used, including cilostazol and pentoxifylline [13]. In patients who do not improve with exercise and pharmacological treatment, surgical treatment should be considered [17]. The aim of invasive treatment is to extend the distance of intermittent claudication, reduce pain, improve the quality of life, and reduce the risk of cardiovascular complications [18-21]. Numerous randomized clinical trials and meta-analyses indicate also the effectiveness of supervised exercise programs in improving the functioning and quality of life of patients with intermittent claudication [22-28]. In the intermediate stages of the disease (Fontaine stage IIa), the primary intervention consists of physical training [29]. Endovascular or invasive surgical treatment is indicated only in some patients with PAD, in whom physical rehabilitation and conservative treatment have not brought the expected improvement and there is a high risk of developing critical limb ischemia, including the risk of amputation or even death of the patient [30,31]. It is assumed that invasive treatment is undertaken when the claudication distance is 100 m or less, and when the patient has pain at rest and necrotic lesions (III and IV, according to the Fontaine classification) [32-35]. We hypothesize that the improvement in objective parameters, such as ABI, maximal claudication distance (MCD), and pain-free walking distance (PFWD) associated with revascularization, improves subjective parameters, such as quality of life and pain level. Therefore, this study aimed to compare the ABI, MCD, PFWD, claudication pain, and quality of life (intermittent claudication questionnaire [ICQ]) before and 3 months after revascularization surgery in 98 patients diagnosed with PAD at a single center in Poland.

Material and Methods

Ethics Statement

The study protocol was approved by the Local Bioethics Committee of the Nicolaus Copernicus University in Toruń and Ludwik Rydygier Collegium Medicum in Bydgoszcz (No. KB 331/2019) and conducted in accordance with the Helsinki Declaration of 1975. Written informed consent was obtained from the enrolled patients.

Inclusion and Exclusion Criteria

This prospective observational study included 98 adult patients with symptomatic PAD, treated with endovascular procedures (balloon angioplasty) and classic surgery (age ≥18 years <85, Fontaine stage IIb, claudication distance <100 m). The recruitment took place in the Clinic of Vascular Surgery and Angiology, University Hospital No. 1 in Bydgoszcz, Poland, between April 2019 and January 2022. Medical records were reviewed 1 to 5 days before planned revascularization to acquire the following data: type of planned revascularization, age, cardiovascular and non-cardiovascular comorbidities, laboratory results, previous course of the disease, and PAD-specific data (symptoms, Fontaine score, results of ultrasonography and MRA). Patients were qualified for the procedure on the basis of a clinical and angiographic examination (performed by a vascular surgeon), which was obtained from medical records. Clinical evaluation included Fontaine scale and ABI (diagnosis of PAD if rest ABI ≤0.9). Patients were eligible for the study if they had been diagnosed with PAD and had scheduled revascularization surgery (endovascular treatment with balloon angioplasty and classic surgery) and previous conservative therapy had failed. Initially, 117 patients with PAD were enrolled in the study, and 98 patients were included in the final analysis (Figure 1).
In this study, we assessed the following parameters: ABI value, claudication distance (both PFWD and MCD), and pain intensity on an 11-point numeric rating scale (NRS11) scale. To assess health-related quality of life, we used the intermittent claudication questionnaire (ICQ) specific for patients with claudication. Dyslipidemia and arterial hypertension were defined by prior medical diagnosis. Smoking, age, and disease duration were defined at the time of interview. The patients were examined twice: just before the surgery (1-5 days before) and 3 months after.

**ABI Measurements**

We used a non-directional Doppler with the EZ8 probe (MD2 Multi Dopplex® II, Huntleigh, Arjo, Inc., Addison, IL, USA) to measure the ABI. Preparation for the examination included prohibition of drinking coffee and smoking 2 h before the examination and 20 min of rest in the supine position on a re-habilitation table in a room with a temperature in the range of 21 to 24°C. Blood pressure measurements were always taken in the following order: right brachial artery, right dorsal artery of the foot, right posterior tibial artery, left dorsal pedis artery, left posterior tibial artery, left brachial artery, right brachial artery again (measurements were repeated to exclude false hypertension resulting from emotions and white coat syndrome) [36]. The results of the measurements were obtained by dividing the highest systolic blood pressure measured in the arteries of the lower extremities (dorsal pedis and posterior tibial arteries) by the highest systolic blood pressure measured in the brachial arteries [37]. During the study, the Doppler probe was placed in specific locations: to the posterior region of the medial malleolus when examining the posterior tibial artery; on the dorsum of the foot to verify the dorsal artery of the foot; and in the area of the cubital fossa of the arm to assess the flow wave of the brachial artery. The obtained ratio of measurements considered normal for adults ranged from 0.90 to 1.30, while ratios less than 0.9 indicated the presence of PAD [38,39]. The lower the ABI value, the more clinically advanced PAD and more advanced ischemia of the lower limb [40,41].

**Assessment of Intermittent Claudication Distance (PFWD and MCD) and Pain Intensity (NRS11)**

The examination was performed on a treadmill (Schwinn Fitness 810, Nautilus, Inc., Vancouver, WA, USA), according to the Gardner-Skinner protocol. The running speed of the treadmill was constant at 3.2 km/h. Every 2 min of walking, the inclination angle of the treadmill was increased by 2%, until it reached a maximum value of 12% [42,43]. Patients were instructed how to signal the first pain in the limb while walking or possible deterioration of well-being, which required the test to be stopped. During the walking test, the PFWD was assessed and measured in meters, until the first pain in the lower limb appeared (calf, foot, buttock, thigh). The patient assessed the intensity of pain for the first time, and then continued walking until severe pain appeared, preventing further activity and requiring rest. On this basis, the MCD was assessed. The patient

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**Figure 1.** The process of screening patients (made in draw.io v21.6.5, JGraph Ltd).

Inclusion criteria were (1) patients aged ≥18 years <85 years; (2) diagnosis of PAD; (3) qualification for endovascular or classic surgery treatment; (4) waiting for planned revascularization 1 to 5 days before the procedure; and (5) claudication distance < 100 m;

Exclusion criteria were (1) lower limb amputation, (2) patients with known and treated diabetes as well as those with a current fasting blood-glucose level >125 mg/dL, (3) pain in limbs at rest, (4) acute limb ischemia, (5) leg necrosis or ulcers, (6) disability and other factors preventing the treadmill test (including the use of assistive devices while moving, acute cardiovascular conditions, recent myocardial infarction, III-IV degree heart failure according to NYHA, diseases of the musculoskeletal system and the osteoarticular system) (7) sensory disorders, and (8) neurological and autoimmune diseases that can interfere with the interpretation of test results.

**Assessment Methods**

In this study, we assessed the following parameters: ABI value, claudication distance (both PFWD and MCD), and pain intensity on an 11-point numeric rating scale (NRS11) scale. To assess health-related quality of life, we used the intermittent claudication questionnaire (ICQ) specific for patients with
assessed the intensity of maximum pain. We used the NRS11 to assess pain intensity, with 0 representing no pain, and 10 representing worst pain imaginable [44]. Patients were asked not to take analgesics 5 h before the scheduled examination.

**Quality of Life Assessment with ICQ**

The ICQ contained 16 questions about the severity of the problem, severity of symptoms, and the impact of intermittent claudication on the patient’s daily life. The answers were scored in the range from 0 to 5 points, and then summed. A higher score indicated a significant severity of the problem and greater limitations caused by intermittent claudications. The total sum of the test scores ranged from 0 (indicating good quality of life) to 80 (indicating poor quality of life). The final results were converted into percentages, where the maximum score was 80 points (meant 100%). The questionnaire contained written instructions for the patients to answer the questions on their own. Before returning the questionnaires, the completeness of the answers provided by the patients was checked. Only completely and correctly completed questionnaires were included in the final analysis.

**Statistical Analysis**

The sample size was estimated based on the Central Statistical Office report from 2018. Estimation was calculated according to the following formula:

\[ n = \frac{u^2 \cdot m \cdot (1 - m)}{d^2} = 28.64 \]

*Where:*
- \( n \) = sample size
- \( m \) = estimated proportion in population (\( m – \) fraction size, \( n – \) population size)
- \( d \) = margin of error
- \( u_z \) = z-score resulting from the confidence level.

**Statistical Methods**

Equity of variance and normality of data distribution were tested with Levene and Kolmogorov-Smirnov tests, respectively. All results presented in the text and tables are expressed as means±standard deviation or number and percentage. ABI, PFWD, MCD, NRS, and ICQ score parameters were compared using t tests, while the Pearson \( \chi^2 \) test was applied to all categorical variables. A value \( P<0.05 \) was considered statistically significant. Statistical analysis was conducted using Python 3.8.10 (libraries: pandas version 1.4.2, scipy version 1.7.1, matplotlib version 3.5.1).

**Results**

**Characteristics of the Study Group**

The study group included 98 patients with PAD (65.77±7 years old, male/female: 81.63%/18.37%), who accepted the invitation for the interview and the examination before and after revascularization surgery. The duration of disease was an average of 3.94±2 years. Patients at high cardiovascular risk participated in the study. Risk factors included dyslipidemia (100%), hypertension (76%), and active smoking (80.61%). The common comorbidities in patients with PAD were myocardial infarction (22.45%), cerebrovascular disease (14.29%), and any tumor without metastasis (7.14%).

**Measurements of ABI, PFWD, MCD and Pain Level**

The follow-up visit 3 month after revascularization showed that patients with PAD had significantly higher ABI, PFWD, and MCD compared with measurements before surgery. Statistically significantly lower pain levels were demonstrated during PFWD and MCD. The average ABI value increased by 0.22±0.09 (\( P<0.001 \)). The average PFWD increased by 53.57±20.13 m (\( P<0.001 \)) after surgery. The average MCD increased by 121.77±78.34 m (\( P<0.001 \)). The level of pain intensity after surgery decreased on average by 1.21±0.87 (\( P<0.001 \)) during PFWD and by 1.13±0.66 (\( P<0.001 \)) during MCD on the NRS11 scale. The differences were statistically significant (Table 1).

**Correlation of ABI, PFWD, MCD, ICQ, and Pain Levels with Disease Duration and Age**

The longer the duration of the disease, the lower was the improvement of the following parameters: PFWD (\( P<0.001 \)), MCD (\( P<0.001 \)), ABI (\( P<0.001 \)), and ICQ (\( P<0.001 \)). The correlation between pain during PFWD (\( P=0.02 \)) and MCD (\( P<0.001 \)) and disease duration was statistically significant, but the value of this correlation was weak (-0.28). There was no statistically significant correlation between age and improvement in all assessed parameters except for MCD (\( P=0.003 \)), but this correlation was weak (-0.30).

**Results of Quality of Life and Functional Efficiency Measurements (ICQ)**

The results of the ICQ showed that the greatest limitations in the daily activity of patients with PAD resulted from the need to stop and rest many times (more than 3 times a day) (4.99±0.10) and the high intensity of pain (4.80±0.39). Intermittent claudication also limited walking more than 1500 m (4.78±0.51), climbing stairs (4.74±0.53), and using public transport (4.56±0.78). Patients also reported limited ability to work and to deal with everyday matters, such as shopping and going to the post...
Table 1. Comparison of the values of the assessed parameters (pain-free walking distance, maximal claudication distance, ankle-brachial index, pain level, duration of disease and age of patients) before and after the revascularization surgery.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Results before and after surgery (n=98)</th>
<th>t-Student test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average±SD</td>
<td>Q1,Q3</td>
</tr>
<tr>
<td>ABI before</td>
<td>0.40±0.09</td>
<td>0.33, 0.44</td>
</tr>
<tr>
<td>ABI after</td>
<td>0.62±0.13</td>
<td>0.53, 0.71</td>
</tr>
<tr>
<td>PFWD before</td>
<td>26.64±11.01</td>
<td>19.25, 30.75</td>
</tr>
<tr>
<td>PFWD after</td>
<td>80.21±23.68</td>
<td>65.00, 97.00</td>
</tr>
<tr>
<td>MCD before</td>
<td>60.08±22.64</td>
<td>41.00, 73.75</td>
</tr>
<tr>
<td>MCD after</td>
<td>181.85±85.35</td>
<td>112.75, 206.75</td>
</tr>
<tr>
<td>Pain PFWD before</td>
<td>7.26±1.13</td>
<td>7.00, 8.00</td>
</tr>
<tr>
<td>Pain PFWD after</td>
<td>6.05±1.30</td>
<td>5.00, 7.00</td>
</tr>
<tr>
<td>Pain MCD before</td>
<td>9.24±0.65</td>
<td>9.00, 9.00</td>
</tr>
<tr>
<td>Pain MCD after</td>
<td>8.11±0.83</td>
<td>8.00, 9.00</td>
</tr>
</tbody>
</table>

Correlations between evaluated variables

<table>
<thead>
<tr>
<th>Variable 1**</th>
<th>Variable 2</th>
<th>Pearson correlation</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFWD***</td>
<td>Duration of PAD</td>
<td>-0.59</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>-0.14</td>
<td>0.17</td>
</tr>
<tr>
<td>MCD***</td>
<td>Duration of PAD</td>
<td>-0.62</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>-0.30</td>
<td>0.003</td>
</tr>
<tr>
<td>ABI***</td>
<td>Duration of PAD</td>
<td>-0.47</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>-0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>Pain PFWD</td>
<td>Duration of PAD</td>
<td>-0.24</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>-0.14</td>
<td>0.17</td>
</tr>
<tr>
<td>Pain MCD</td>
<td>Duration of PAD</td>
<td>-0.28</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>-0.19</td>
<td>0.06</td>
</tr>
<tr>
<td>ICQ***</td>
<td>Duration of PAD</td>
<td>0.82</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>0.13</td>
<td>0.13</td>
</tr>
<tr>
<td>ABI</td>
<td>PFWD</td>
<td>0.56</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ABI</td>
<td>MCD</td>
<td>0.56</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ABI</td>
<td>Pain PFWD</td>
<td>0.34</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ABI</td>
<td>Pain MCD</td>
<td>0.35</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ABI</td>
<td>ICQ</td>
<td>-0.39</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>PFWD</td>
<td>ICQ</td>
<td>-0.52</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>MCD</td>
<td>ICQ</td>
<td>-0.52</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

* Analysis of the final results using the Student’s t-test for dependent samples; ** means improvement after surgery. SD – standard deviation; PFWD – pain free walking distance; MCD – maximal claudication distance; ABI – ankle-brachial index; ICQ – intermittent claudication questionnaire; Q1 – quartile 1; Q3 – quartile 3.
Intermittent claudication affected social activity (2.73±1.00) and feelings of depression and worrying, but to moderate degree (2.68±0.94). There was an improvement in all areas of the questionnaire (on average by 0.55-1.20 points), except for the need to stop during activity (the difference was 0.00±0.16). The revascularization procedure contributed to a statistically significant improvement in the patients' total functional capacity and total ICQ score (79.92±8.29 vs 60.23±12.36, P<0.001; Table 2).

Discussion

In our study, the study group represented patients with PAD in an advanced clinical stage (IIb Fontaine) who underwent revascularization (balloon angioplasty and classical surgery), in whom conservative treatment did not bring the expected results. This study showed a significant effect of the revascularization procedure on all parameters assessed: ABI values (0.4 vs 0.62, P<0.001), claudication distance PFWD (26.64 vs 80.21, P<0.001), MCD (60.08 vs 181.85, P<0.001), quality of life (81.25 vs 61.25, P<0.001), and pain intensity, which was measured during PFWD (7.26 vs 6.05, P=0.02) and MCD (9.24 vs 6.65, P<0.001). The quality of life (ICQ) in patients with PAD who underwent revascularization significantly improved at 3 months after the procedure.

Table 2. Comparison of changes in specific questions and intermittent claudication questionnaire (ICQ) total score in patients with peripheral arterial disease (PAD) before and after revascularization surgery.

<table>
<thead>
<tr>
<th>No.</th>
<th>Specific questions</th>
<th>Before±SD</th>
<th>After±SD</th>
<th>Difference±SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Intensification of pain</td>
<td>4.80±0.39</td>
<td>3.60±0.68</td>
<td>1.20±0.65</td>
</tr>
<tr>
<td>2.</td>
<td>Crossing the road</td>
<td>3.78±0.80</td>
<td>2.62±1.00</td>
<td>1.16±0.76</td>
</tr>
<tr>
<td>3.</td>
<td>Using the bus, train or tube</td>
<td>4.56±0.78</td>
<td>3.55±1.11</td>
<td>1.01±0.86</td>
</tr>
<tr>
<td>4.</td>
<td>Climbing several flights of stairs</td>
<td>4.74±0.53</td>
<td>3.80±0.78</td>
<td>0.94±0.76</td>
</tr>
<tr>
<td>5.</td>
<td>Climbing one flight of stairs</td>
<td>3.72±0.67</td>
<td>2.67±1.00</td>
<td>1.05±0.76</td>
</tr>
<tr>
<td>6.</td>
<td>Walking more than 1500 m</td>
<td>4.78±0.51</td>
<td>3.79±0.79</td>
<td>0.99±0.71</td>
</tr>
<tr>
<td>7.</td>
<td>Walking 100 m</td>
<td>3.60±0.72</td>
<td>2.46±0.85</td>
<td>1.14±0.86</td>
</tr>
<tr>
<td>8.</td>
<td>Going out of the house</td>
<td>3.64±0.96</td>
<td>2.61±1.04</td>
<td>1.03±0.79</td>
</tr>
<tr>
<td>9.</td>
<td>Number of rests caused by leg pains</td>
<td>4.99±0.10</td>
<td>4.99±0.13</td>
<td>0.00±0.16</td>
</tr>
<tr>
<td>10.</td>
<td>Time spent thinking about leg pains</td>
<td>3.98±0.68</td>
<td>2.82±0.78</td>
<td>1.16±0.90</td>
</tr>
<tr>
<td>11.</td>
<td>Time spent feeling downhearted and low because of leg pains</td>
<td>2.67±0.81</td>
<td>1.68±0.82</td>
<td>0.99±0.95</td>
</tr>
<tr>
<td>12.</td>
<td>Worrying that leg pains would get worse</td>
<td>2.68±0.94</td>
<td>1.90±0.72</td>
<td>0.78±0.79</td>
</tr>
<tr>
<td>13.</td>
<td>Interference with normal work</td>
<td>4.29±0.80</td>
<td>3.14±0.86</td>
<td>1.15±1.08</td>
</tr>
<tr>
<td>14.</td>
<td>Interference with hobbies or pastimes</td>
<td>4.09±0.94</td>
<td>2.95±0.84</td>
<td>1.14±0.99</td>
</tr>
<tr>
<td>15.</td>
<td>Interference with social activities</td>
<td>2.73±1.00</td>
<td>2.18±0.84</td>
<td>0.55±1.16</td>
</tr>
<tr>
<td>16.</td>
<td>Interference with doing errands (shopping, going to the post office or bank, etc.)</td>
<td>4.30±0.76</td>
<td>3.42±0.81</td>
<td>0.88±0.91</td>
</tr>
<tr>
<td></td>
<td>Total ICQ score**</td>
<td>79.92±8.29</td>
<td>60.23±12.36</td>
<td>19.69±0.21</td>
</tr>
</tbody>
</table>

* Mean: SD – standard deviation; t – analysis of the final results using the Student’s t-test for dependent samples; p – statistical significance level. ** ICQ – intermittent claudication questionnaire
In our study, 3 months after revascularization, the ABI increased by 0.22, which should be considered clinically significant. Migdalski et al [45] reported that an increase in ABI of at least 0.15 gives a significant clinical improvement. However, the deterioration of the patient's health, noticeable in clinical symptoms, appears already when the ABI decreases by at least 0.1. Research confirming such a relationship was also conducted by McDermott et al [41], in which patients had ABI measured before and immediately after revascularization. In 41% of the operated patients, only a slight increase in ABI value, ie, <0.15, was observed immediately after surgery. The baseline mean ABI value of 0.62 indicated a less advanced clinical stage than in our own study, in which the mean ABI value before surgery was 0.40. Patients who showed no or slight increase in ABI value <0.15 also did not gain any benefit in improving other indices: efficiency during walking and physical activity. In our own study, an average improvement in ABI of 55% was obtained after 3 months. The benefits of revascularization in patients with PAD are closely related to the improvement of the ABI value [46].

In our study, owing to the symptoms of PAD and the decision of the surgeon, revascularization was the main form of treatment. Supervised exercise therapy is recommended for less advanced clinical stages of PAD (Fontaine IIa), and its effects are mainly related to MCD prolongation rather than ABI improvement [47]. In our study, after only revascularization, a positive effect was obtained in the form of improvement in ABI, PFWD, and MCD. Supervised training is a perfect complement to treatment after revascularization [48]. The improvement in MCD in our study may seem small compared to some studies [47-50]. However, when combined with improved quality of life and reduced pain, it is significant. In studies shortly after surgery (<1 month), patients show a greater improvement in claudication distance than in long-term studies >3 months. Therefore, it should be taken into account that the original benefits of revascularization gradually decline over time, and continuation of treatment with exercise should be implemented [51]. Koellemay et al [52] recommend starting treatment with conservative therapy, and in the case of its failure, using revascularization. The meta-analysis of Fakhry et al [48] showed that the best effects in the form of improvement of PFWD and MCD in patients with intermittent claudication are attained with combination therapy, ie, a combination of revascularization with supervised physical training or pharmacotherapy. Klaphake et al [53] also confirmed this in their research. In turn, the study of Nordanstig et al [54] showed that patients undergoing revascularization achieved a greater improvement in PFWD than did those treated conservatively. Also Momsen et al [55] showed that better results in improving PFWD, MCD, and quality of life were achieved by patients undergoing revascularization than by those treated conservatively.

In our study, we achieved a reduction in pain during both PFWD and MCD. The decrease in the average pain intensity according to the NRS may seem small, but it is statistically significant, and together with the increase in the length of the intermittent claudication distance, it is a very beneficial effect. This is also confirmed by other studies [50,56]. Many authors in their studies emphasize the low quality of life of patients with PAD [57-59]. Our study also showed an improvement in ICQ quality of life 3 months after revascularization. Our study showed that the greatest limitations in the daily activity of patients with PAD before the procedure resulted from the need to stop and rest many times and the high intensity of pain. We showed that intermittent claudication had the lowest, but moderate effect on social activity and feelings of depression. However, many authors emphasize that depression often accompanies PAD in patients [60,61]. Remes et al [62] showed that both endovascular revascularization and classic surgery improved the quality of life of patients with PAD. However, compared with the control group, the patients with PAD still exhibited depressive behavior. The study by Vlajinac et al [63] showed an improvement in the quality of life of patients after classic surgery, assessed 1 year after surgery. In turn, Petersohn et al [64] showed that the improvement in the quality of life after revascularization was still maintained 2 years after the procedure. The improvement of the quality of life after revascularization is confirmed by numerous studies by other authors [65,66]. Poredos et al [67] showed that the quality of life of patients after revascularization procedure improved in a study 4 to 6 weeks after the procedure. Improvement in quality of life significantly correlated with improvement in claudication distance, even when ABI improvement was not significant. A study by Golledge et al [68] assessed claudication distance and quality of life (ICQ) in patients with PAD. It has been shown that quality of life is significantly correlated with the results of the 6-minute walk test. Other authors also emphasized the relationship between the length of the claudication distance and quality of life [69,70]. In addition, our study showed that the longer the duration of the disease, the lower the improvement in all parameters assessed. This is a very important conclusion that emphasizes the role of prevention, early detection, and treatment of PAD for increasing the effectiveness of therapy. The evolution of atherosclerosis takes many years and initially develops asymptptomatically. This highlights the need to expand preventive screening for early detection of PAD [71]. Screening studies show that up to 17.5% of the population over 75 years of age have asymptomatic PAD [72]. The ABI examination should become a routine examination in primary health care for patients over 50 years of age with risk factors. Early detection of PAD enables the implementation of conservative treatment such as walking, training, and leveling risk factors such as obesity, smoking, improper diet [73].
Limitations of the Study

The findings of this study should be interpreted after consideration of the strengths and weaknesses of the investigation. We did not include BMI data in the study, and there are studies that indicate the influence of body weight on the length of the claudication distance [74,75]. The study did not differentiate patients according to the type of revascularization performed (classic, endovascular, hybrid). Endovascular therapy is associated with a lower risk of complications, while the classic procedure is more effective in long-term studies [76]. We excluded patients with diabetes from the study, but it should be remembered that a very high percentage of patients with PAD also have diabetes [77]. We decided to exclude these patients because of possible abnormal ABI, abnormal pain sensation due to neuropathy, and high incidence of ulceration. Our study also did not assess patients’ physical activity levels within the 3 months after surgery. The beneficial effect of physical activity on the length of the claudication distance is confirmed by numerous studies [78-80]. However, our study included patients who were qualified for revascularization due to the fact that conservative therapy did not bring the expected results (Fontaine IIb and claudication distance <100 m). Revascularization is currently the best form of treatment in very advanced clinical stages of PAD (Fontaine IIb, III, and IV), when treatment with physical exercise does not bring the expected results [81]. Our study included the assessment of parameters 3 months after the procedure. However, long-term studies show a gradual deterioration of the assessed parameters, ie, ABI and claudication distance [81-83]. Owing to the gradual management of PAD, in addition to the necessary revascularization, special attention should be paid to the implementation of conservative treatment methods that will maintain the benefits of the performed revascularization [84,85].

Conclusions

The revascularization surgery performed in the course of PAD significantly improves the blood supply to the lower limbs, expressed as the ABI index. The PFWD and MCD significantly increase within 3 months of revascularization surgery. The improvement of objective parameters, such as ABI and intermittent claudication distance, is associated with a significant improvement in subjective parameters, such as quality of life and pain level.

Patients who have had PAD for a shorter period of time achieve greater improvement in the analyzed parameters. In patients with a significantly advanced clinical stage of PAD, revascularization should be chosen as the form of treatment.

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Declaration of Figures’ Authenticity

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